Comparison of AMSR-E Soil Moisture Retrievals to SMOS Retrievals and In-Situ Data

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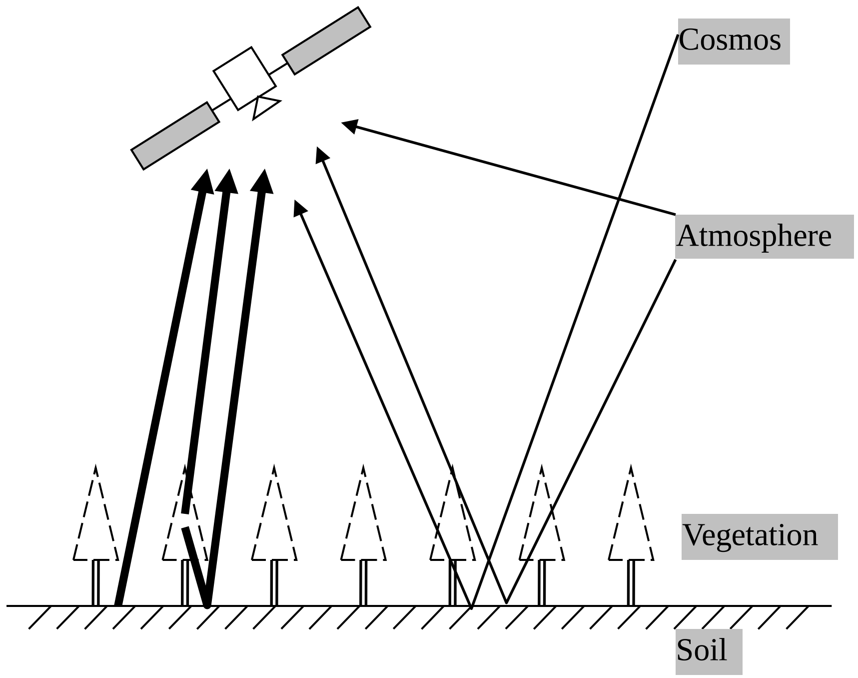
Single-Channel Approach

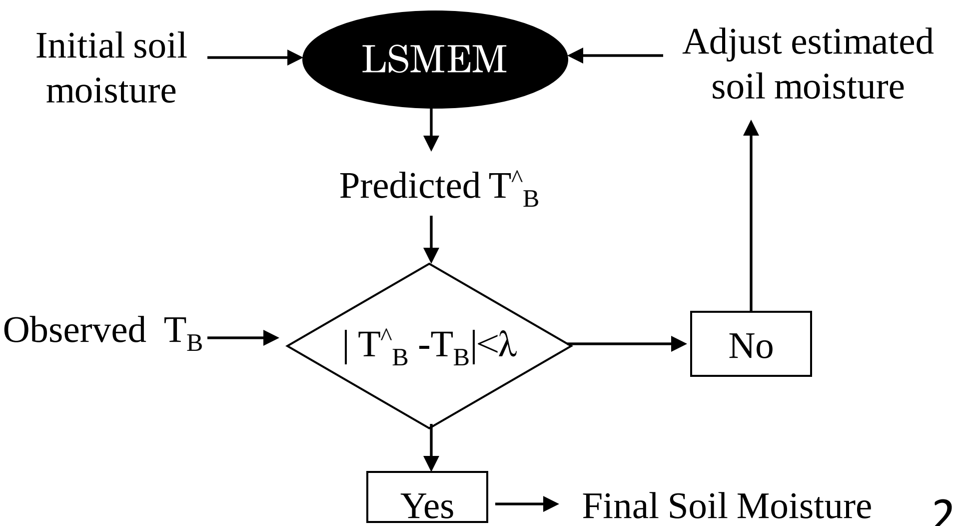
Land Surface Microwave Emission Model (**LSMEM**, Drusch et al.)

- Surface->TOA radiative transfer model
- Based on physical parameters
    - Soil
    - Vegetation
    - Surface properties
    - Surface water



To retrieve soil moisture, a simple inversion (i.e. root finding) is employed to find the soil moisture values that gives the best match to the observed brightness temperature.

- Use single channel/single polarization (for AMSR-E, 10.65 GHz Horizontal)



LSMEM Parameters

Parameter/variable	Value	Data source	Reference
Soil texture (sand/clay fraction) and bulk density	Spatially distributed constants	ISLSCP-IIO	Hall et al., 2005
Soil surface roughness	0.3	Choudhury et al., 1979	
Vegetation coverage/type	Spatially distributed climatology	MODIS, MOD-12 MOD-13	Friedl et al., 2002 Huete et al., 2002
Vegetation water content	Spatially distributed climatology	Based on MODIS LAI and land cover types	Rodell et al., 2004
Water coverage	Spatially distributed constants	MODIS classification	Hansen, et. Al., 2000
Vegetation structure parameter	Constants based on classification	Jackson and Schmugge, 1991	
Vegetation single scattering albedo	0.07	Average value according to Pampaloni and Paloscia, 1986; Ulaby *et al.*, 1983	

Problems and Challenges

- Accounting for the impact of se up and senescence) in the input vege

Better vegetation optical properties in MW frequency

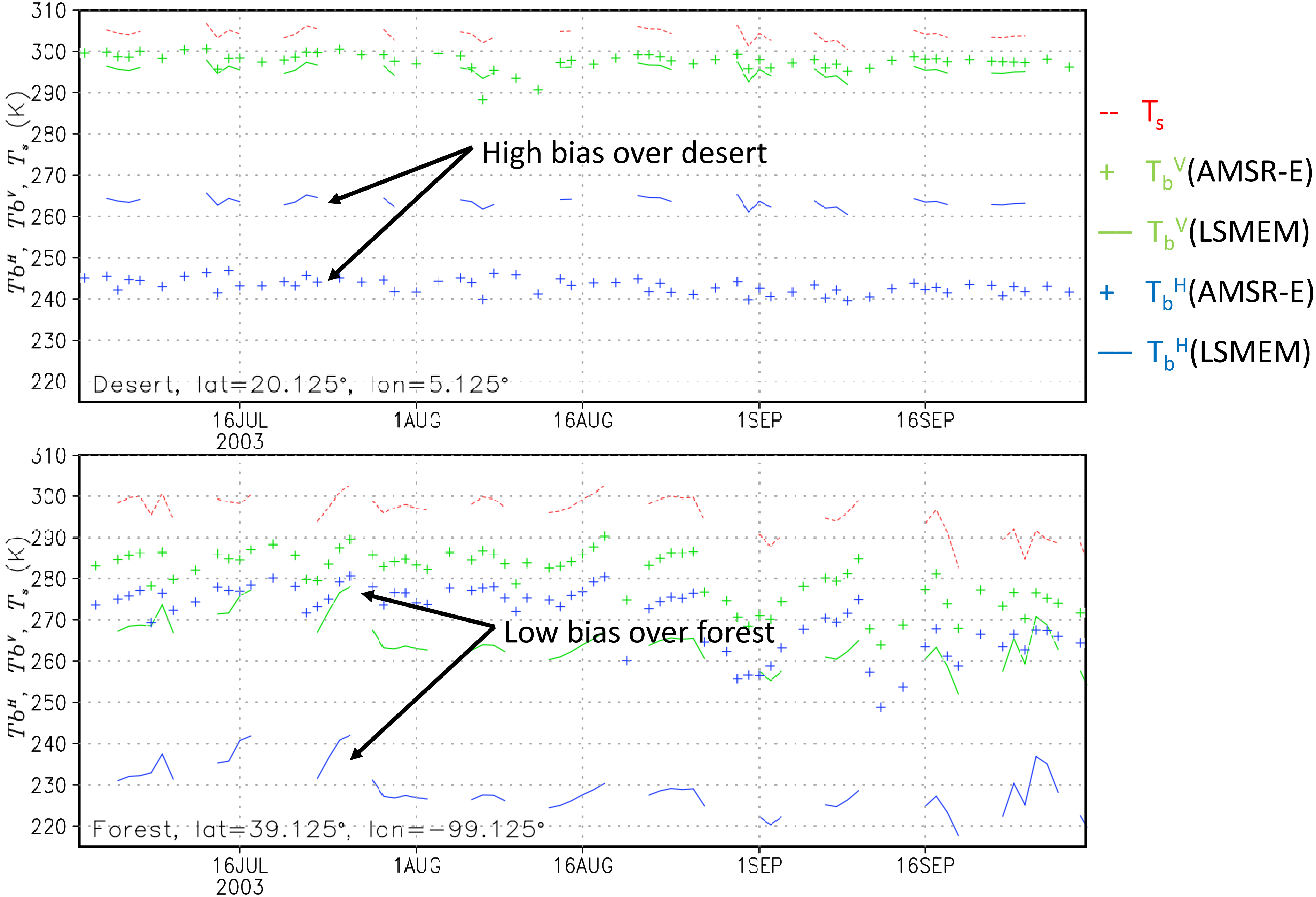
- Due to incorrect surface parameters, the LSMEM (forward model) predicted Tb can be biased against the satellite observations. Consequently, the re incorrect soil moisture values either or 50%).

Parameter calibration (forward model)

- Impacts of active rainfall, snow, frequency interference, and heavy ve

Identification and masking

Forward Model Biases w/o Calibration



Multi-Channel Approach

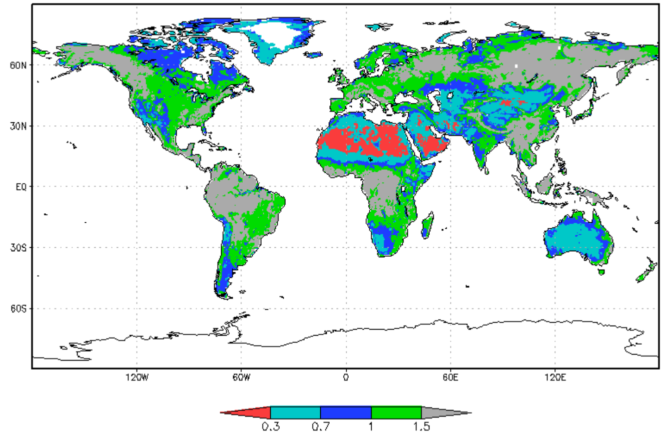
Two Models:

- ❑ LSMEM(retrieval mode): $SM = f\,(VOD, T_b^{10GHz}, \ldots)$
- ❑ UMT(modified): $VOD = g\,(SM, T_b^{10GHz}, T_b^{18GHz}, T_b^{23GHz}, \ldots)$

Iteratively solve the 2 equations for 2 unknowns .

Why:

1. LSMEM provides a very sophisticated parameterization for soil moisture – soil surface emissivity relationship.
2. UMT model (originally solves for SM too) offers a very good VOD estimation.



Vegetation Optical Depth (VOD) estimates from UMT model

Parameter Sensitivity

Parameter/variable	Value	Data source	Reference
Soil texture (sand/clay fraction) and bulk density	Spatially distributed constants	ISLSCP-IIO	Hall et al., 2005
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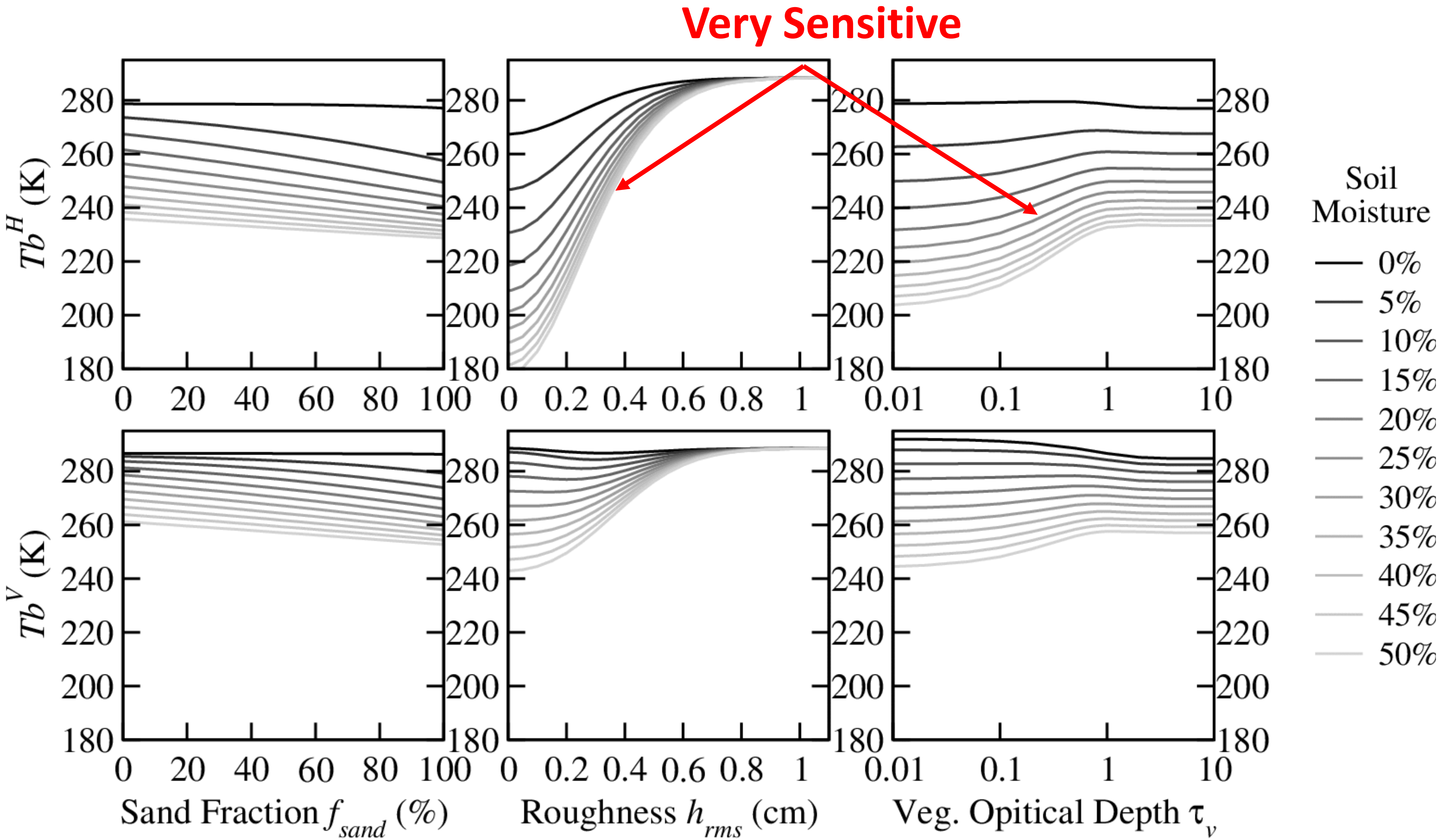
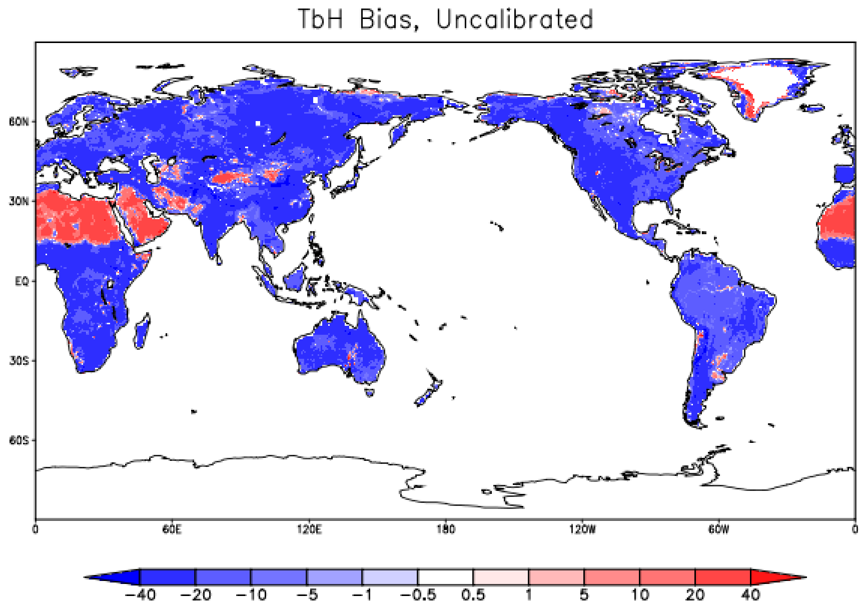
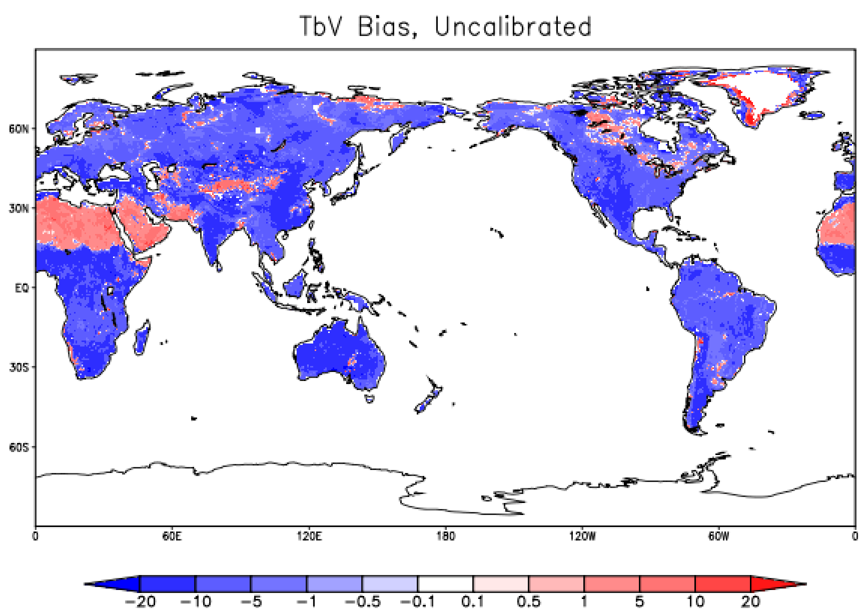
Parameter Sensitivity



LSMEM Calibration

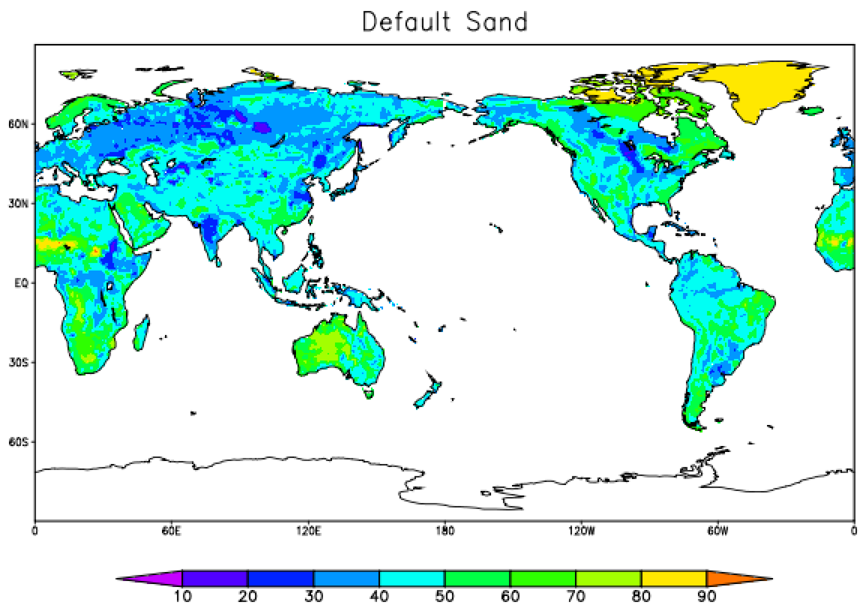


Bias in TbH (K)

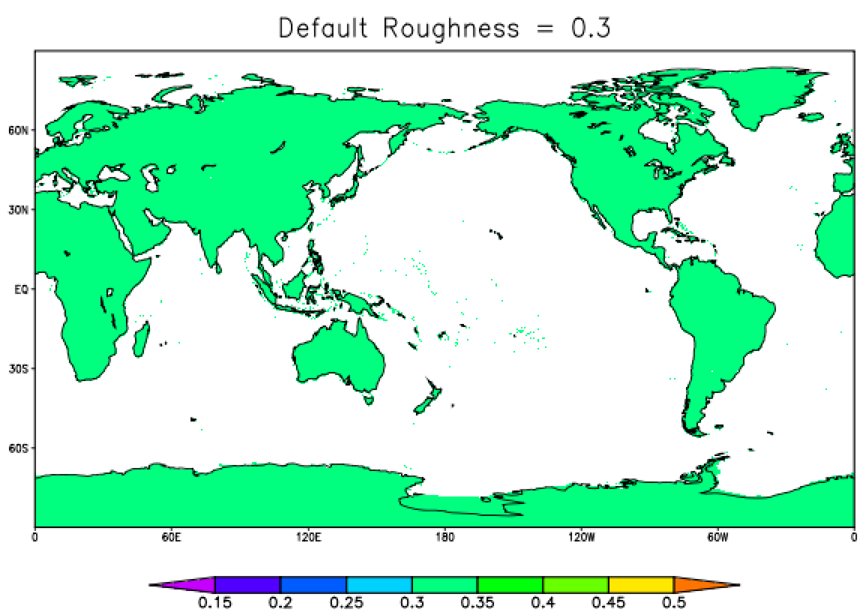


Bias in TbV (K)

LSMEM Calibration

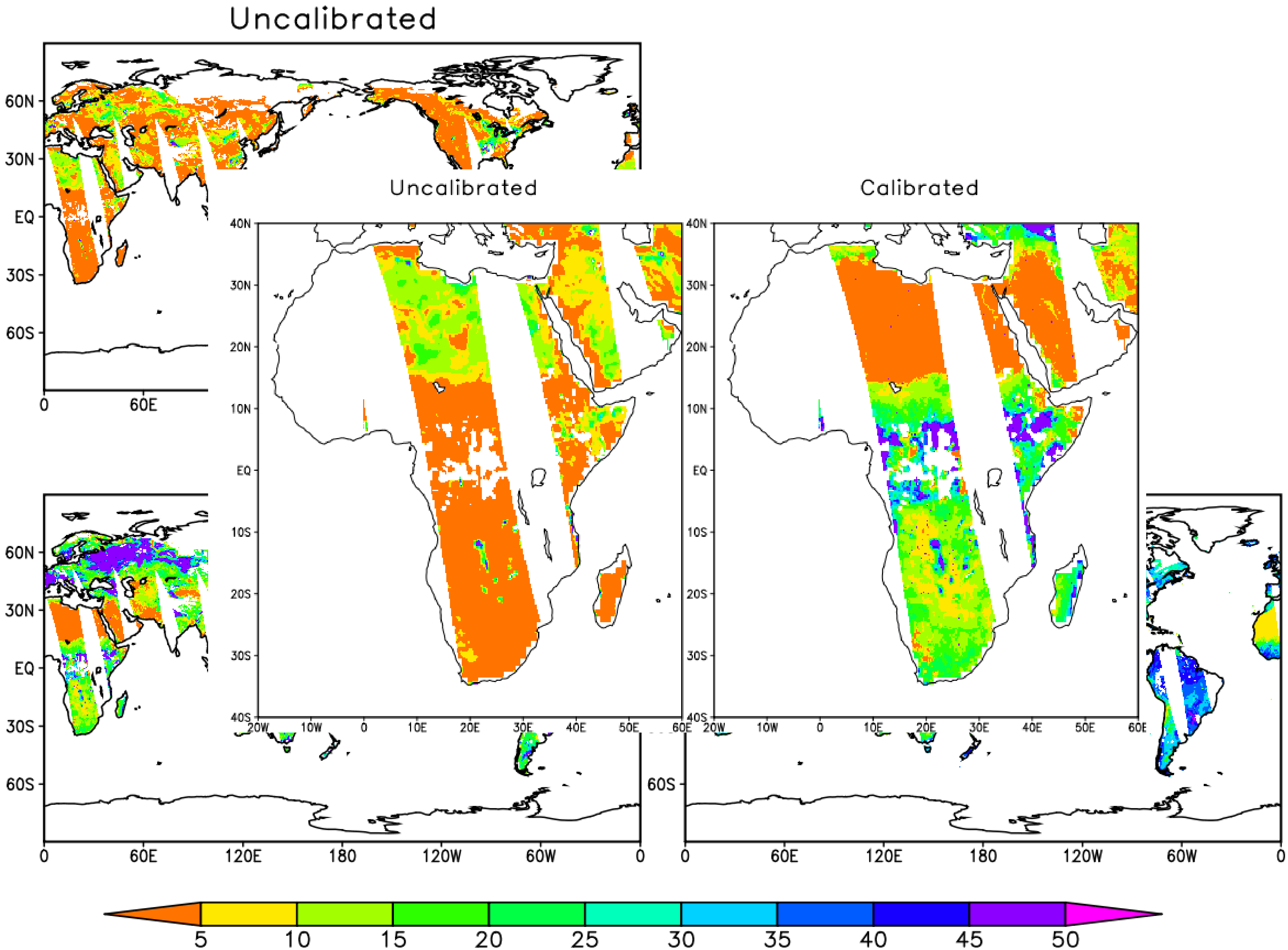


Default Sand Fraction (%)

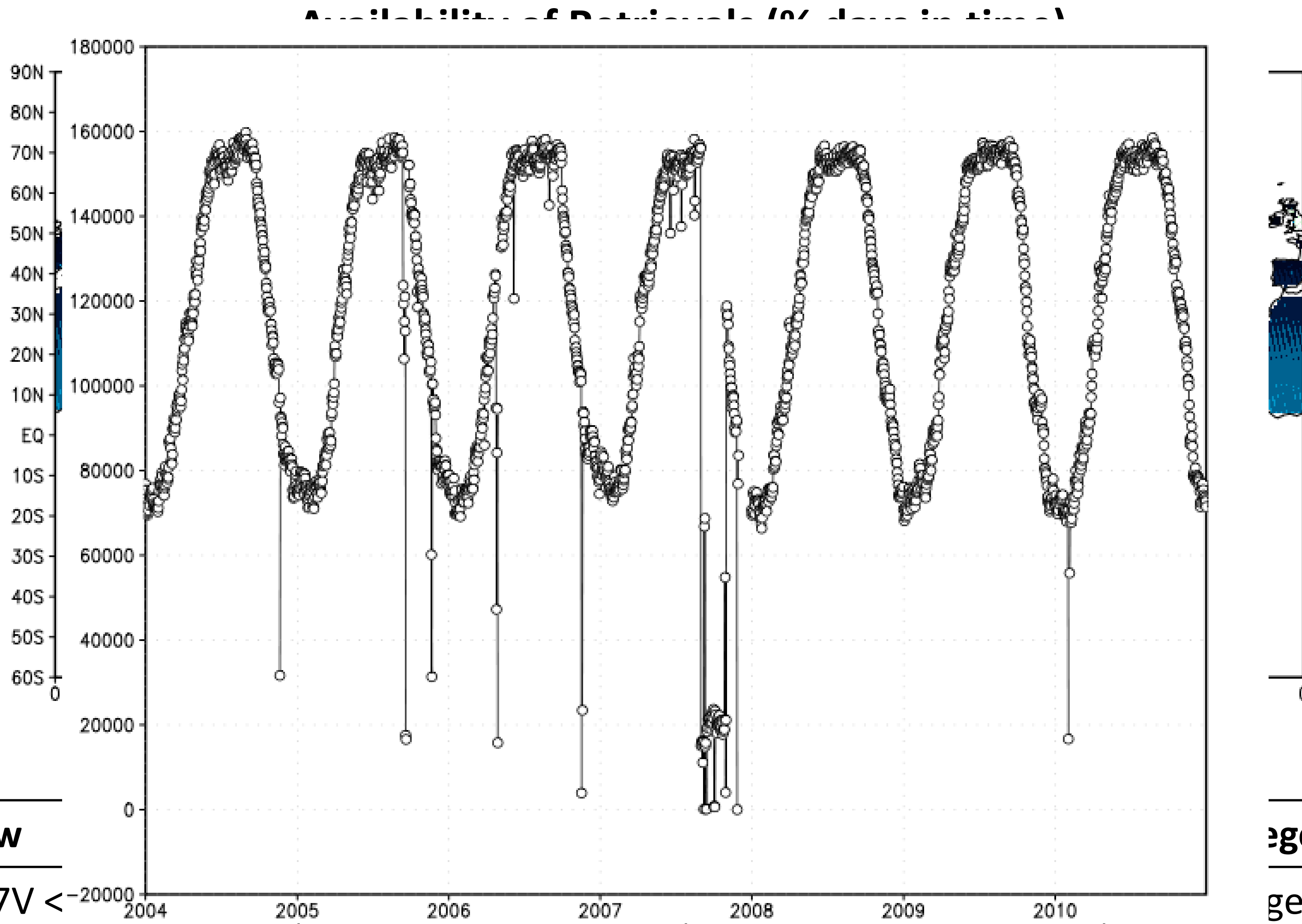


Default Roughness (cm)

LSMEM Calibration



Screening for Rain/Snow/Frozen Ground



Snow			egetation
Tb37V < Tb37V - tb18V < -3 K	and Tb85V < 249 K	Tb18H - Tb10H + 5 < 0 Tb18V - Tb10V + 5 < 0	getation Optical Depth. Not applied yet.

Validation and Comparisons to SMOS L-band Retrievals

AMSR-E Sensor and Data Attributes

Instrument	Polar orbiting (passive microwave radiometer aboard Aqua)
Channels	6 Channels with dual polarization (6.9, 10.7, 18.7, 23.8, 36.5, 89.0 GHz)
Equatorial Crossing Time	1:30 am (Descending); 1:30 pm (Ascending)
Incidence Angle	Single (55^{o})
Soil Moisture Product	Level-3 on EASE grid (Equal-Area Scalable Earth Grid)
Spatial Resolution	~ 25 km
Temporal Resolution	~ 3 days
Vertical Resolution	~ 2 cm
Spatial Coverage	Global
Temporal Coverage	June 2002 to September 2011

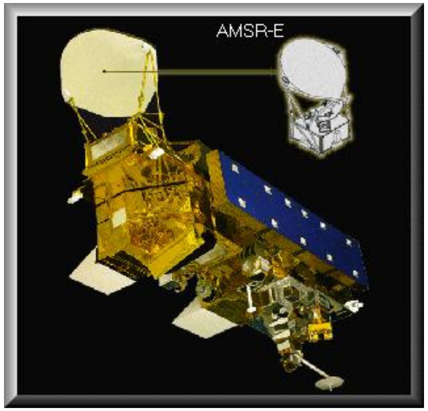
SMOS Sensor and Data Attributes

Instrument	Polar orbiting (a 2-D interferometric radiometer)
Channel	L-band (1.4 GHz)
Equatorial Crossing Time	6 am (Ascending) and 6 pm (Descending)
Incidence Angles	Multiple (from 0^o to 55^o)
Soil Moisture Product	Level 2 on ISEA-4h9 grid (Icosahedral Snyder Equal Area)
Spatial Resolution	~ 43 km
Temporal Resolution	~ 3 days
Vertical Resolution	~ 5 cm
Spatial Coverage	Global
Temporal Coverage	January 2010 to Present

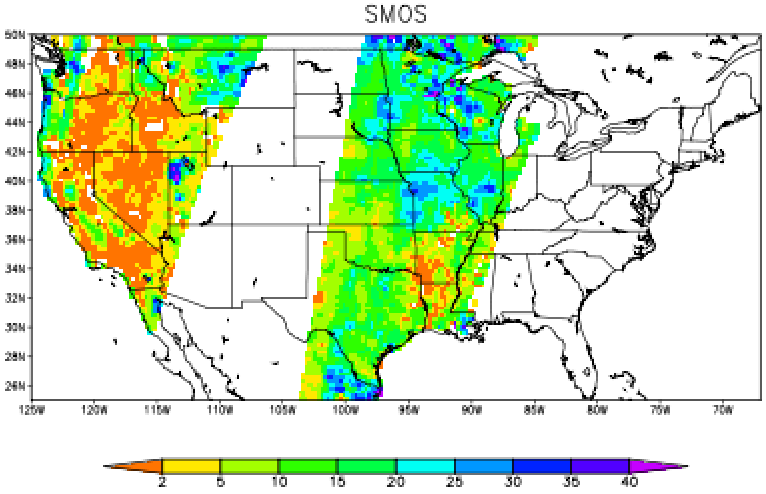
SMOS & AMSR-E

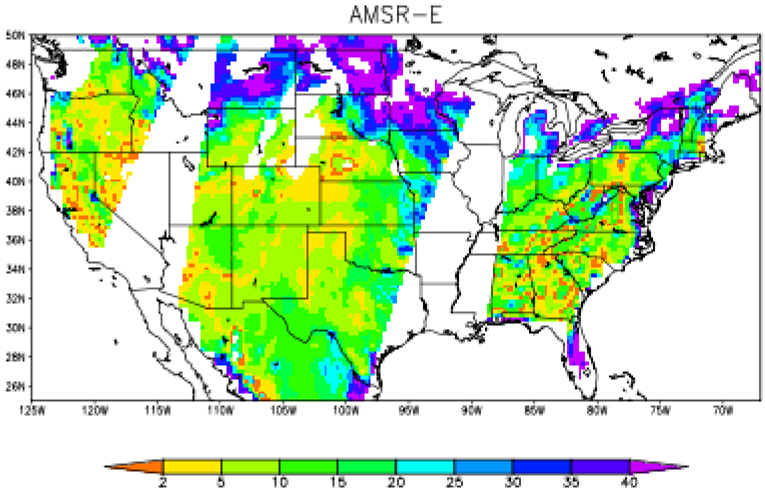
SMOS

AMSR-E



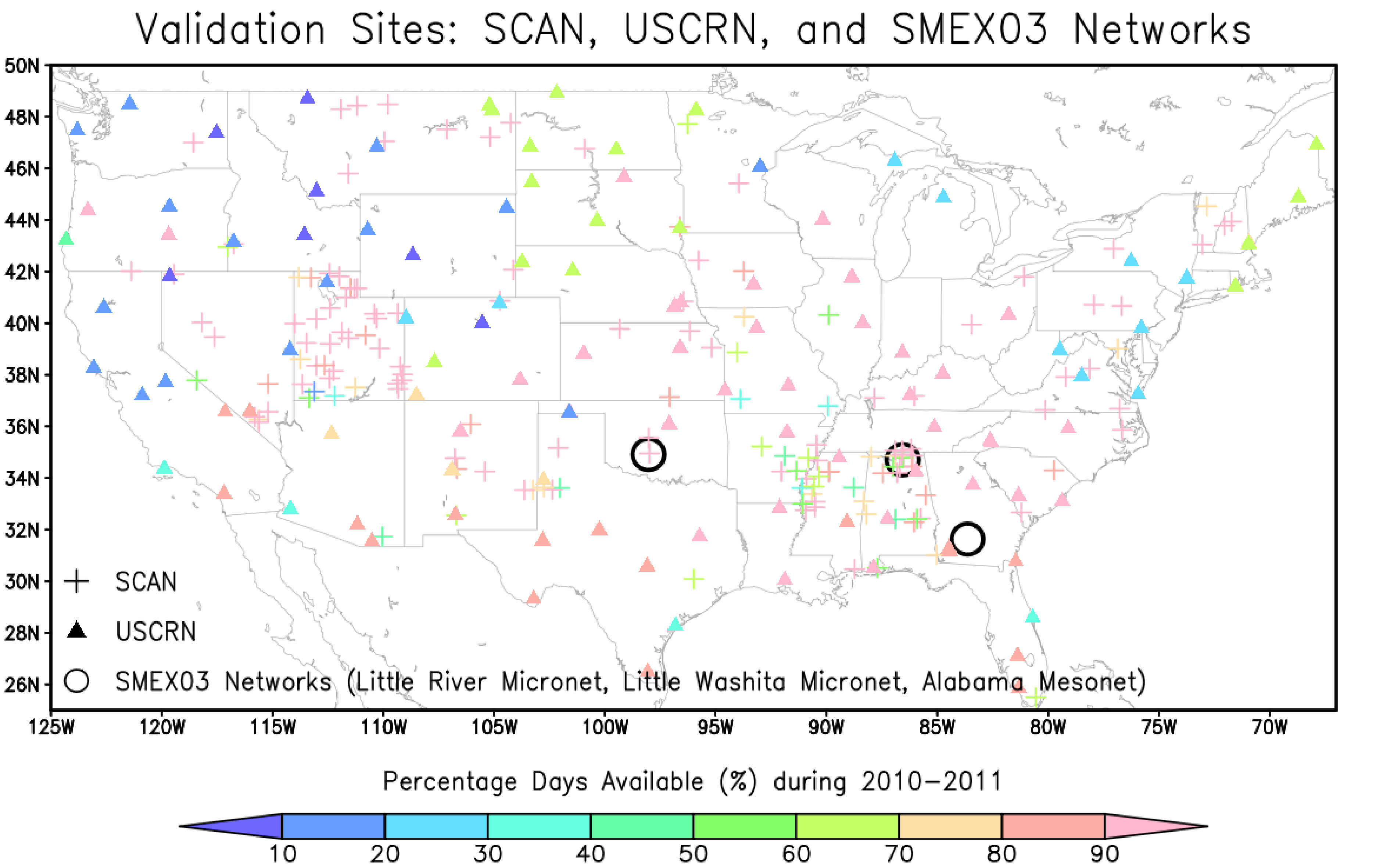
Source: NSIDC



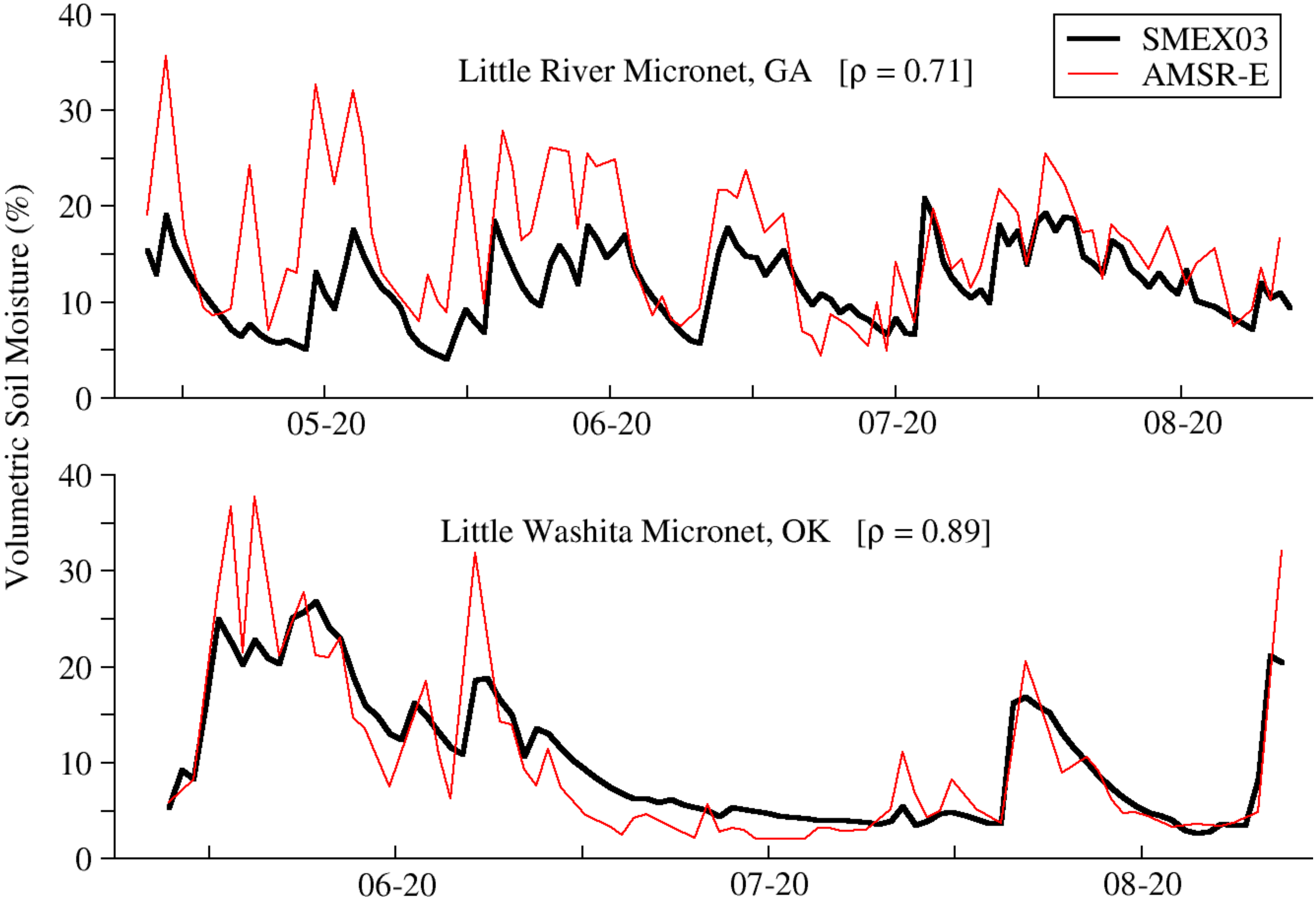


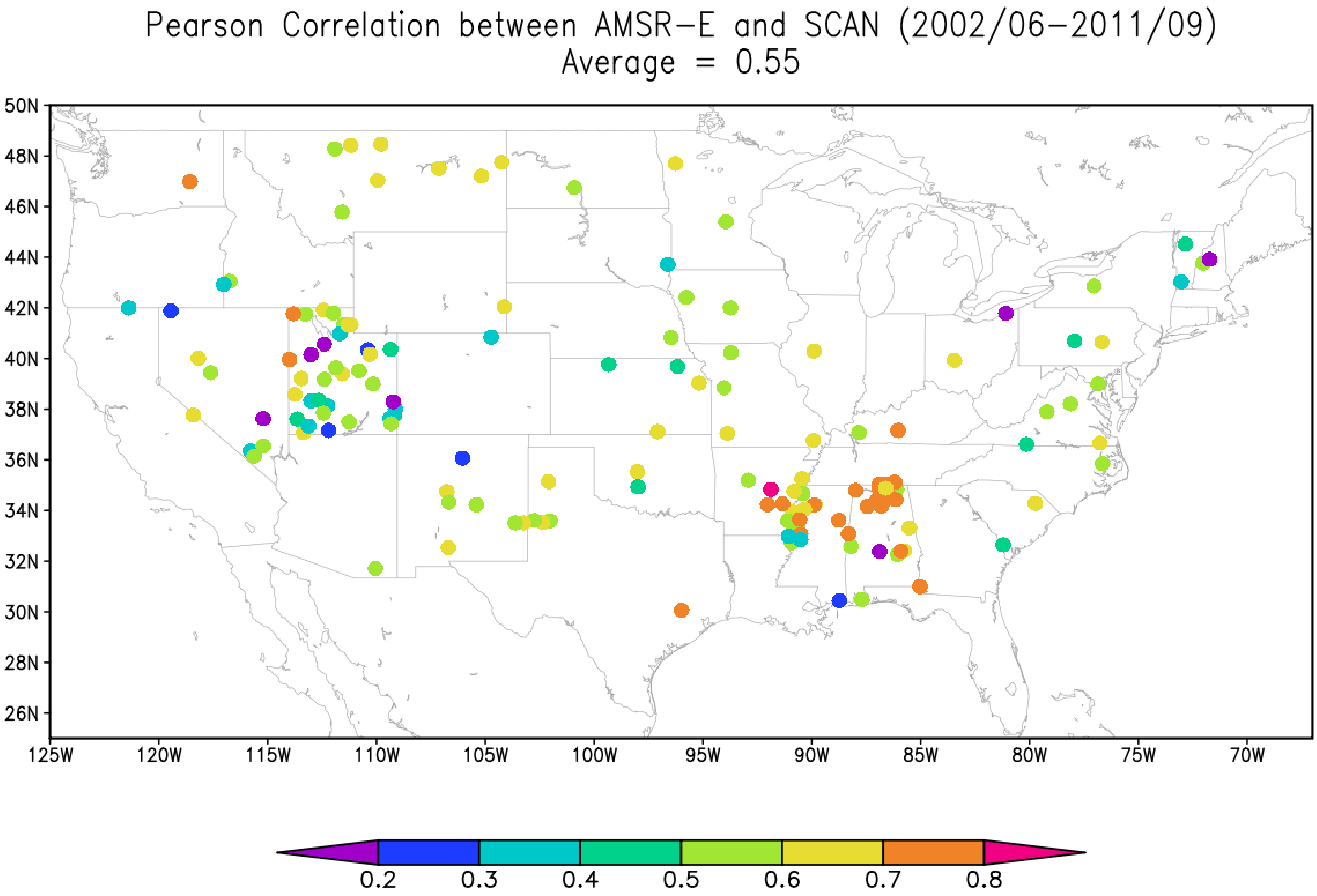
A snapshot of soil moisture (% vol/vol) on **September 6, 2010**

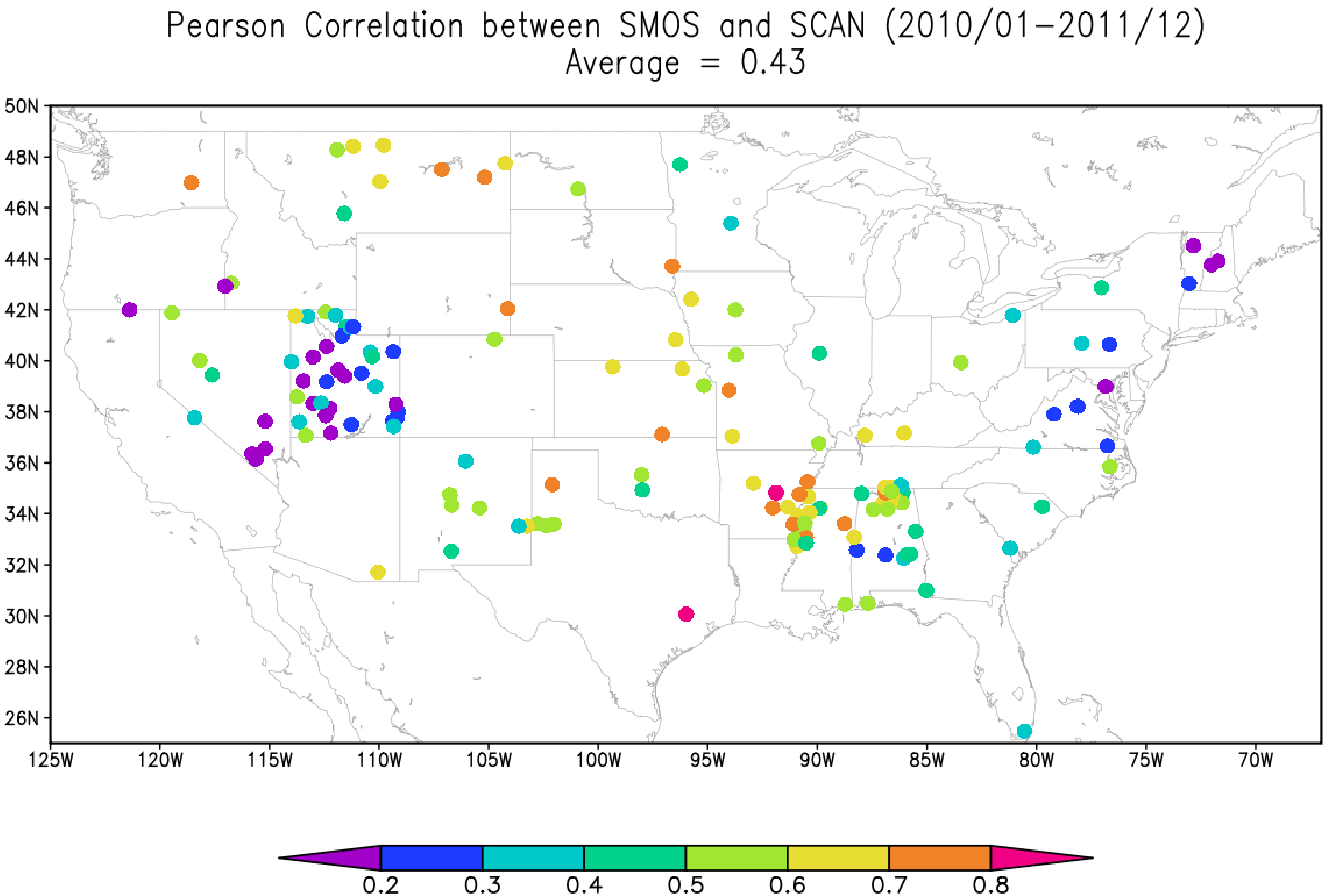
Ground Validation Sites



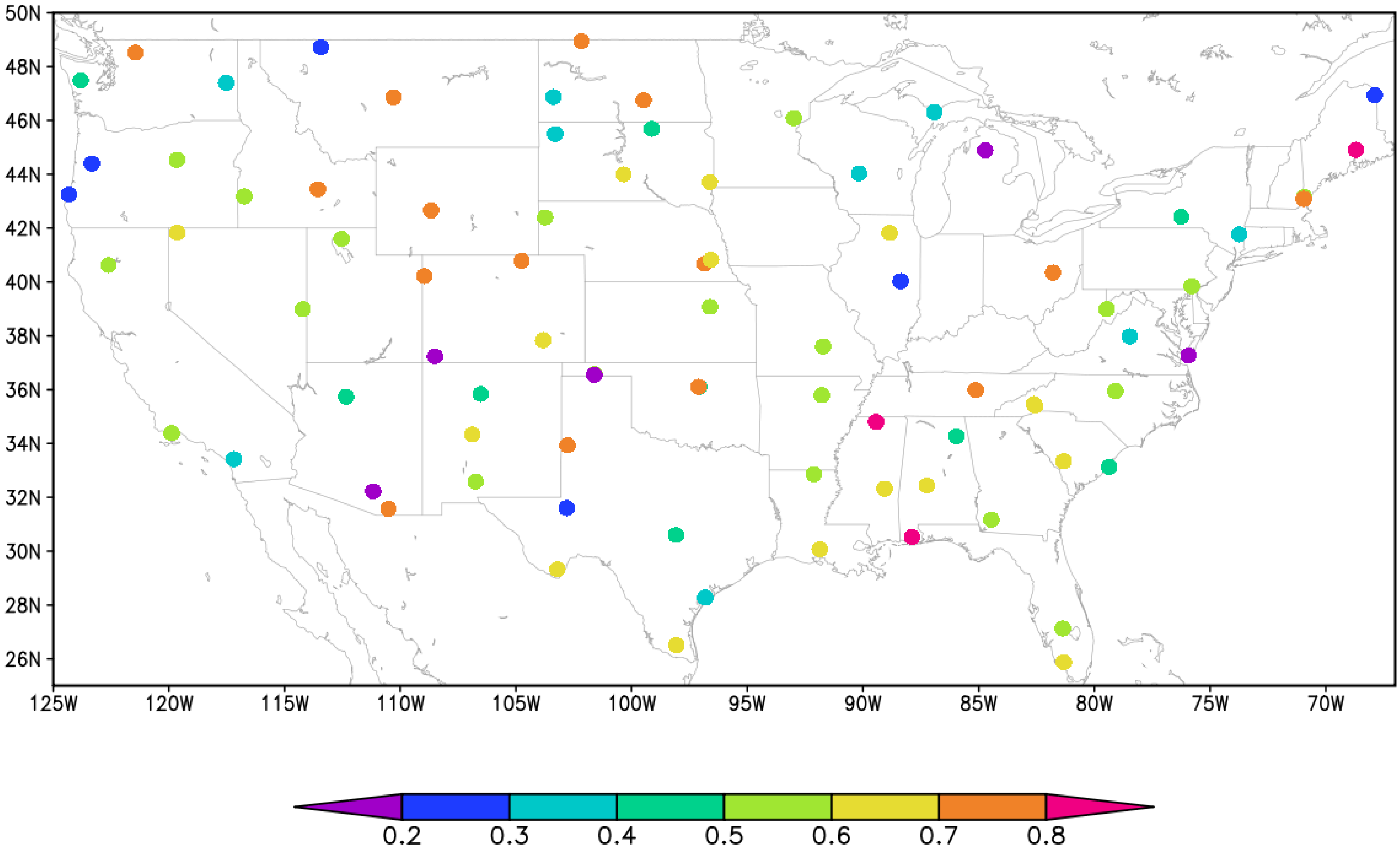
Validation against SMEX03 Micronets Averages

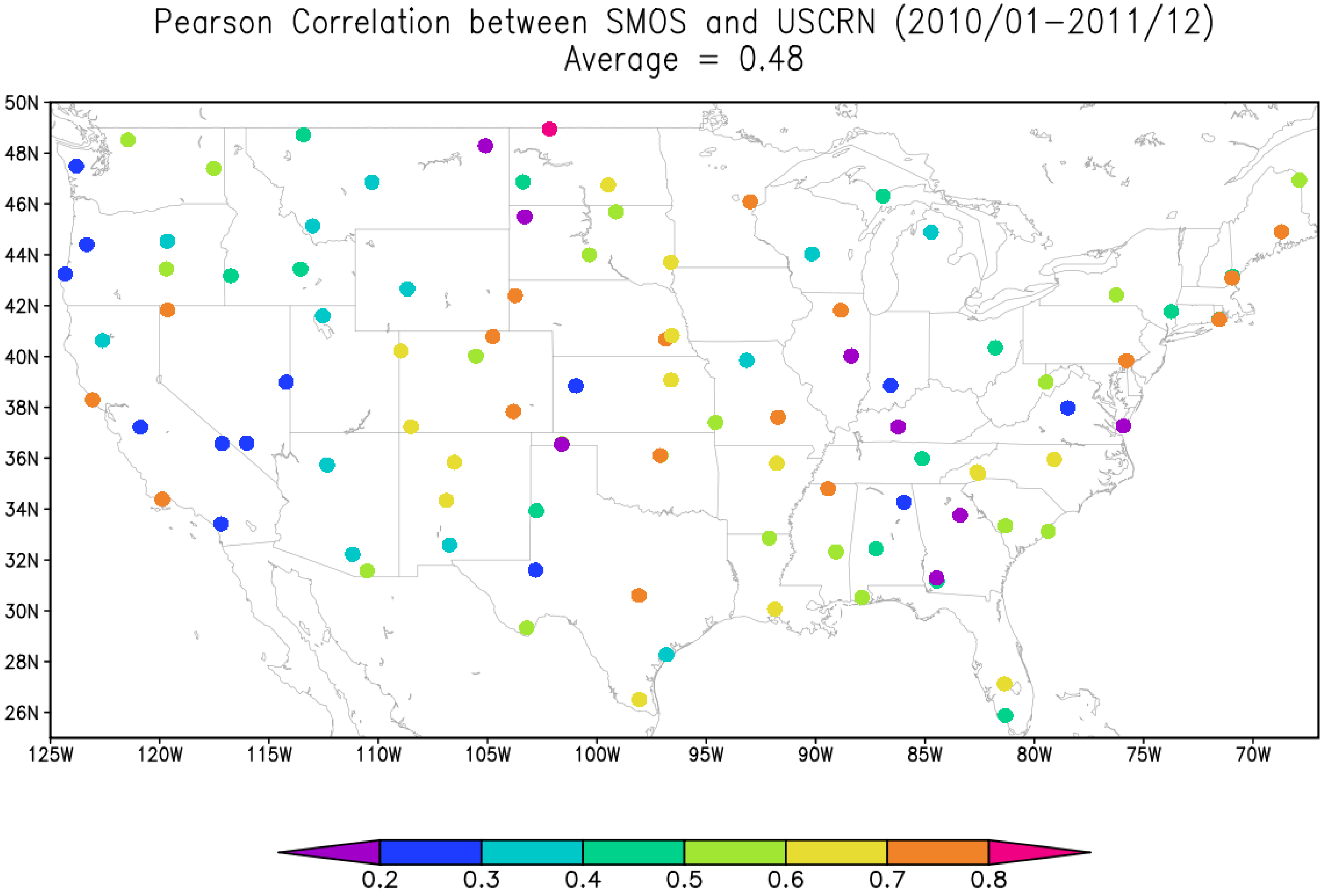



Pearson Correlation between AMSR-E and SCAN (2002/06-2011/09)
Average = 0.55
50N
48N
46N
44N
42N
40N
38N
36N
34N
32N
30N
28N
26N
125W
120W
115W
110W
105W
100W
95W
90W
85W
80W
75W
70W
0.2
0.3
0.4
0.5
0.6
0.7
0.8


Pearson Correlation between SMOS and SCAN (2010/01–2011/12)
Average = 0.43
50N
48N
46N
44N
42N
40N
38N
36N
34N
32N
30N
28N
26N
125W
120W
115W
110W
105W
100W
95W
90W
85W
80W
75W
70W
0.2
0.3
0.4
0.5
0.6
0.7
0.8

Pearson Correlation between AMSR-E and USCRN (2009/06-2011/09)
Average = 0.54





Pearson Correlation between SMOS and USCRN (2010/01–2011/12)
Average = 0.48
50N
48N
46N
44N
42N
40N
38N
36N
34N
32N
30N
28N
26N
125W
120W
115W
110W
105W
100W
95W
90W
85W
80W
75W
70W
0.2
0.3
0.4
0.5
0.6
0.7
0.8

Summary

Source	AMSR-E	SMOS
SMEX03, Little River, GA	0.71 2003/05-2003/08	
SMEX03, Little Washita, OK	0.89 2003/06-2003/08	
SCAN	0.55 (mean) 2002/06-2011/09	0.43 (mean) 2010/01-2011/12
USCRN	0.54 (mean) 2009/06-2011/09	0.48 (mean) 2010/01-2011/12

Comments

- LSMEM/UMT joint model provides a sophisticated parameterization for both surface emissivity and dynamic vegetation optical depth.

- LSMEM (forward model) calibration helps to provide better parameters related to the surface temperature and soil properties, reduce bias in the predicted Tb, and significantly improves soil moisture retrievals.

- Ground validations show very reasonable skills in AMSR-E retrievals. SMOS products are slightly less skillful, primarily due to longer revisit time and less screening for rain/snow conditions.

API and Kalman Filter

Antecedent Precipitation Index (API) Model:

$$API_i = \gamma_i \, API_{i\text{-}1} + P_i$$

API is a simple AR(1) model, where the state variable is an index for the moisture storage.

i = time index, γ = loss coefficient; $\gamma_i = \alpha + \beta \cos(2\pi d/365)$, d = Julian day. We set α = 0.85 and β = 0.10.

Kalman Filter:

Filter Analysis Increment

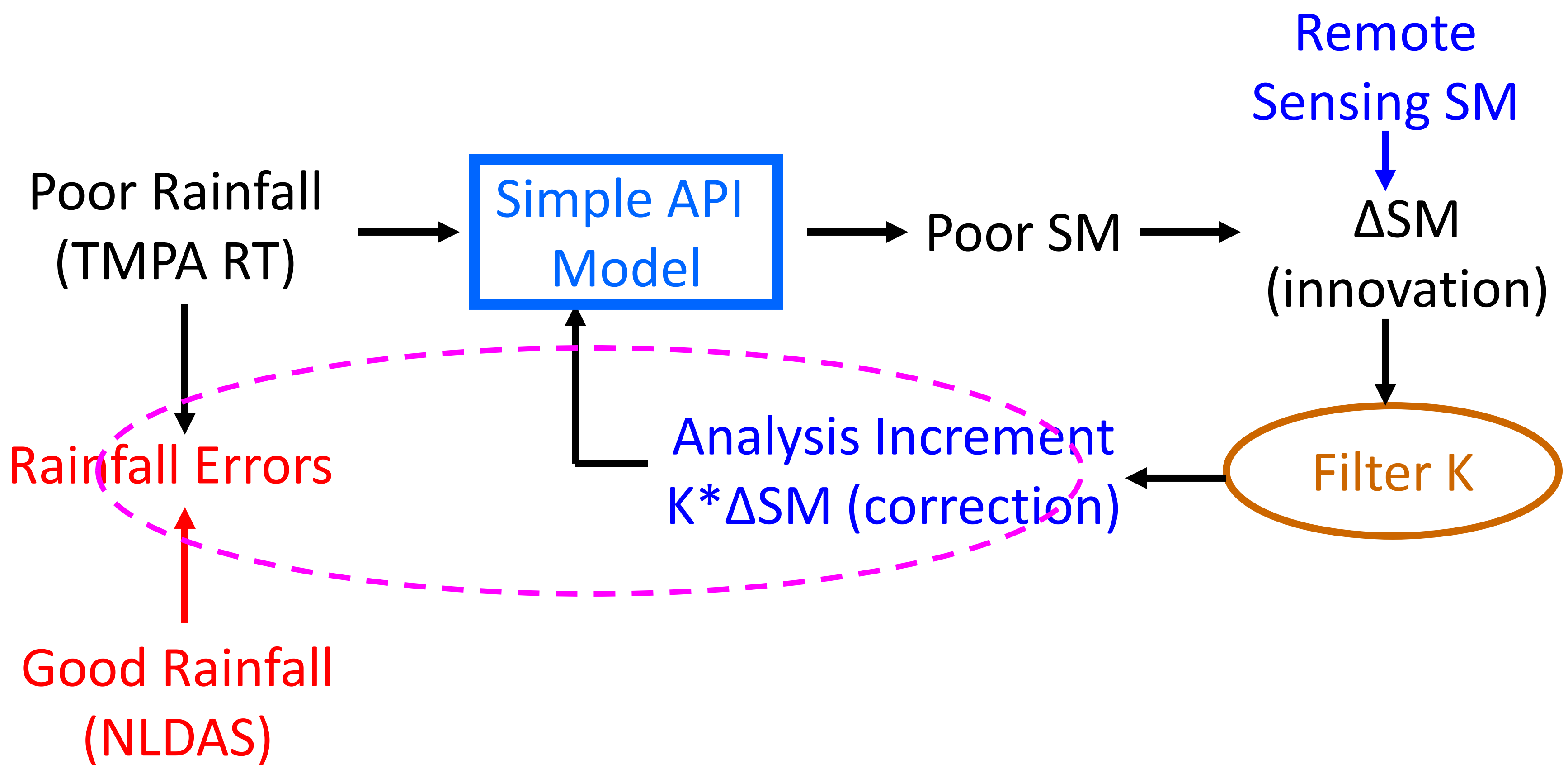
$$API_i^{+} = API_i^{-} + K_i \left(\theta_i - (a + b\, API_i^{-}) \right)$$

Remote Sensing Soil Moisture

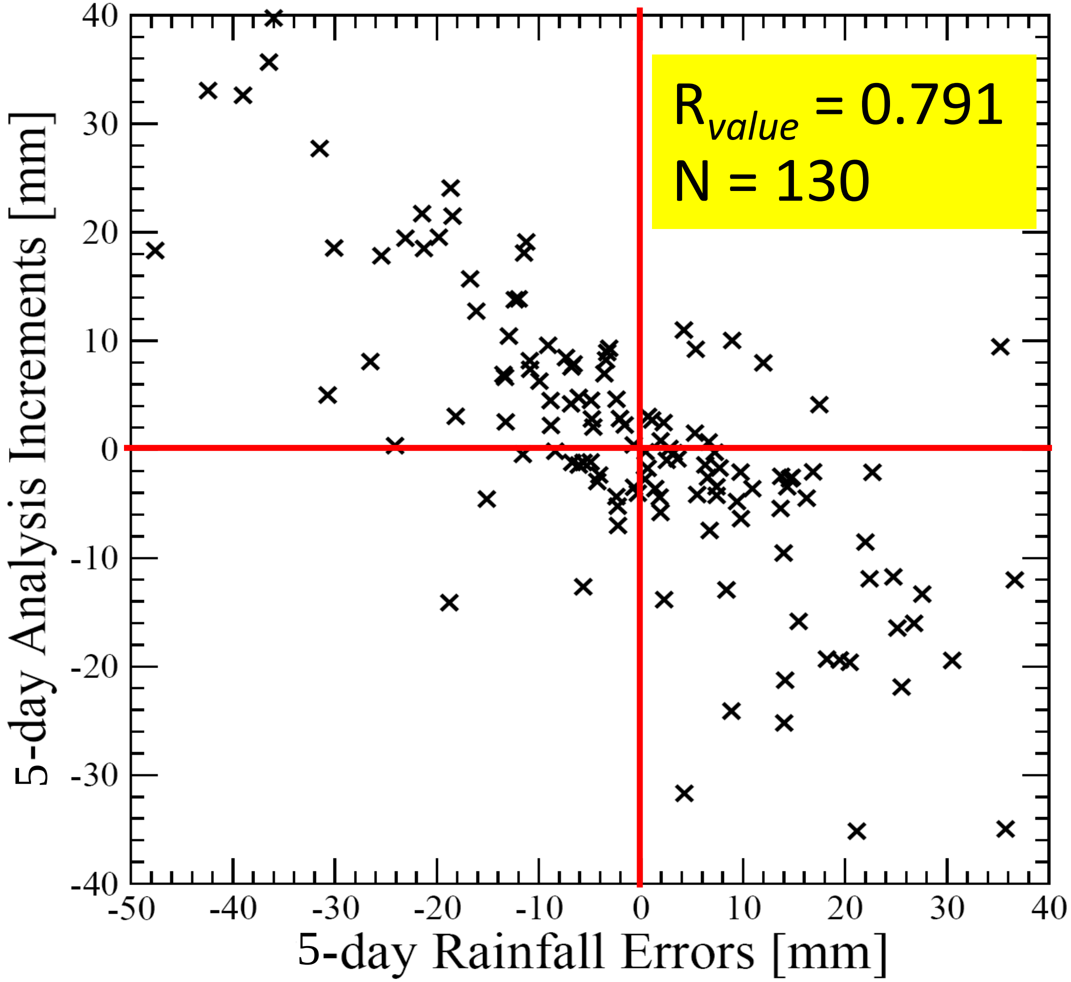
Regression between Soil Moisture and API

R_{value} Proxy Measure

Instead of comparing remotely-sensed soil moisture to ground measurements, we look for **how much the soil moisture product can contribute when it is assimilated into a simplest model for land surface dynamics – the Antecedent Precipitation Index (API) driven by poor rainfall forcings** (Crow and Zhan, 2007).



R_{value} Proxy Measure

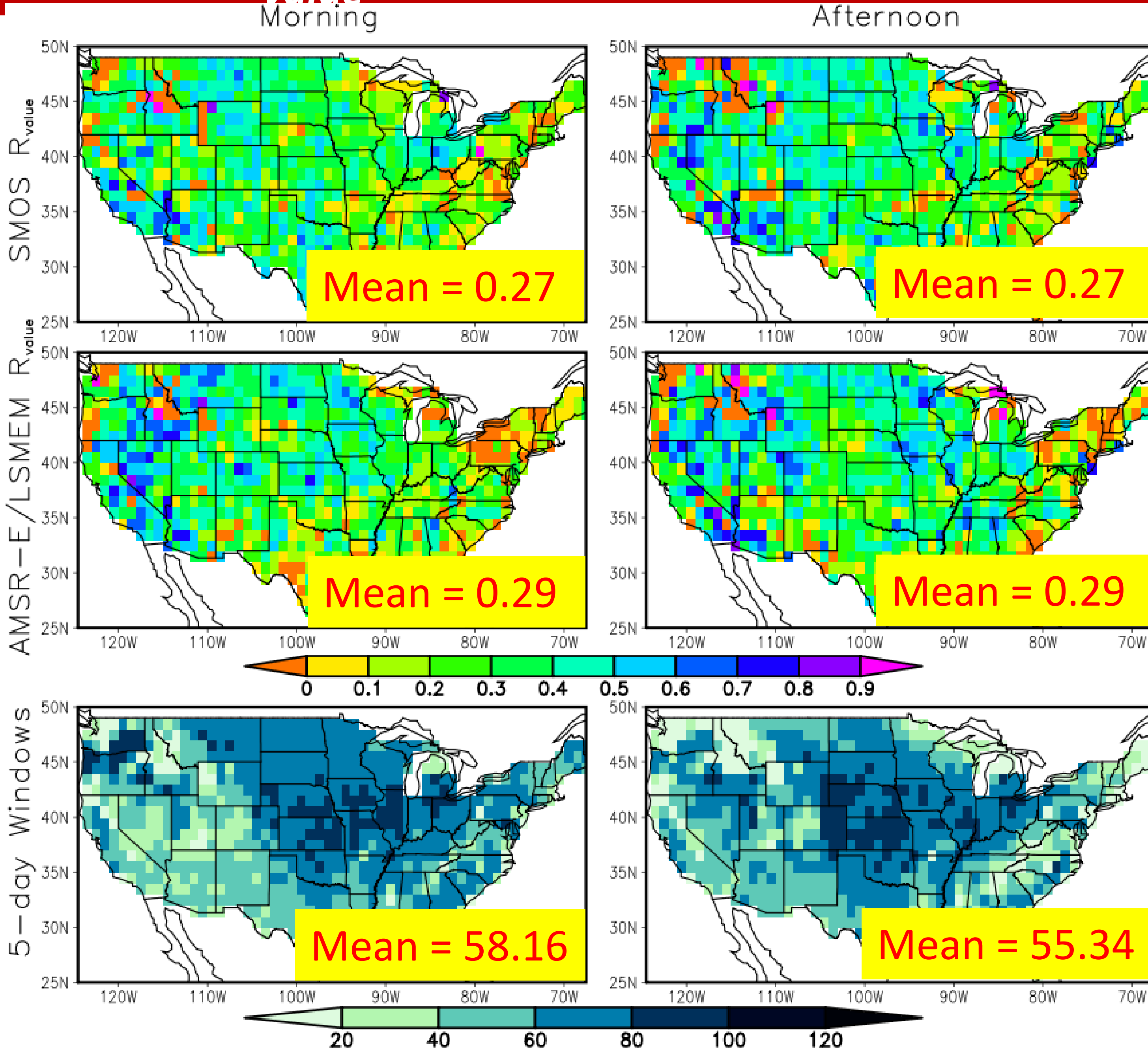


Negative of correlation coefficient (R_{value}) quantifies added remote sensing contribution to the land surface model.

Study setup

Study Period	January 2010 to September 2011
Time Window	5-day window
Data Screening	5-day window includes data only from those days when both the compared SM are available
Geographic Location	Entire Continental USA (but only at SCAN sites when SCAN data are used)

R_{value} Calculated with 5-day windows

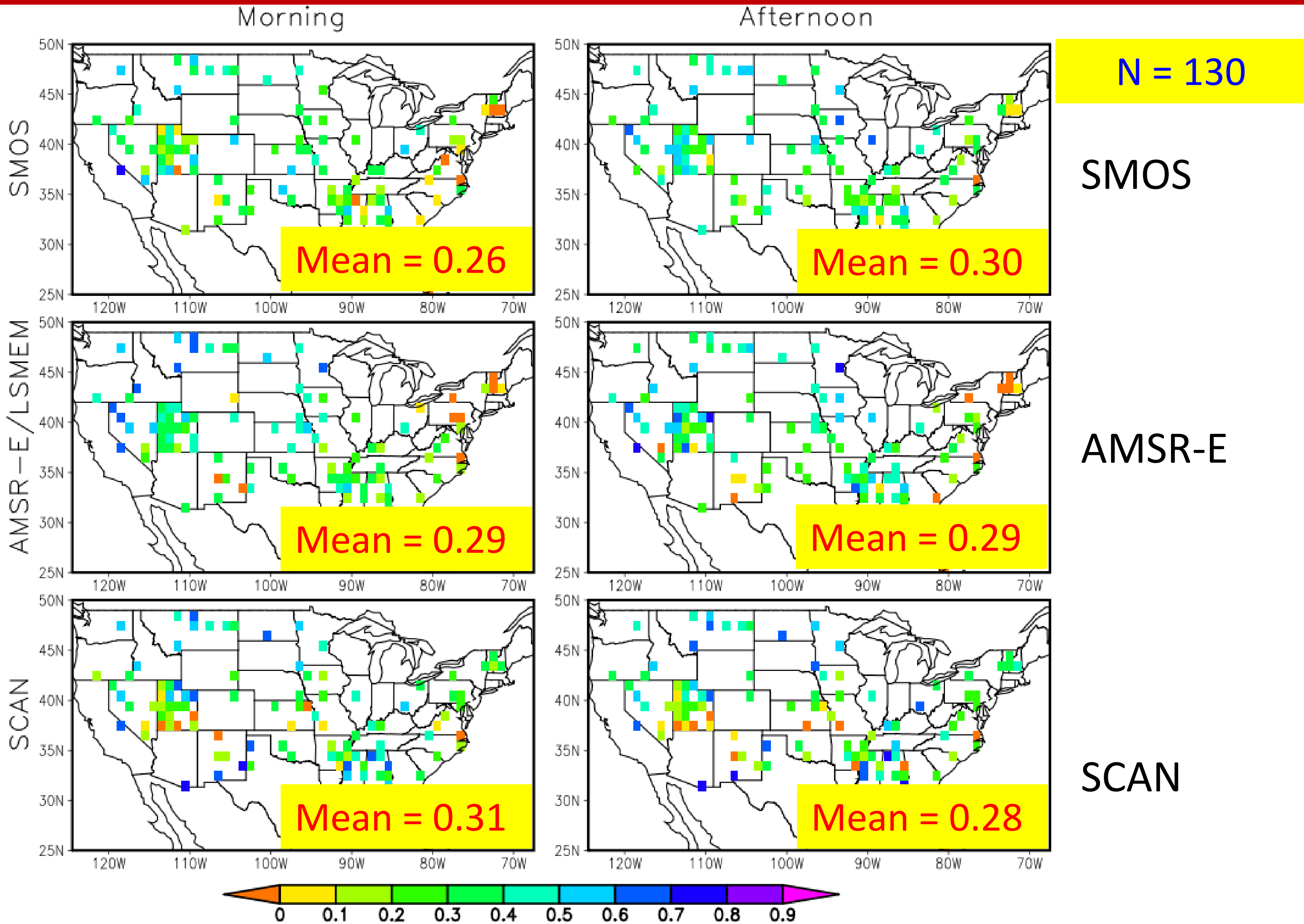


R_{value} Proxy for SMOS

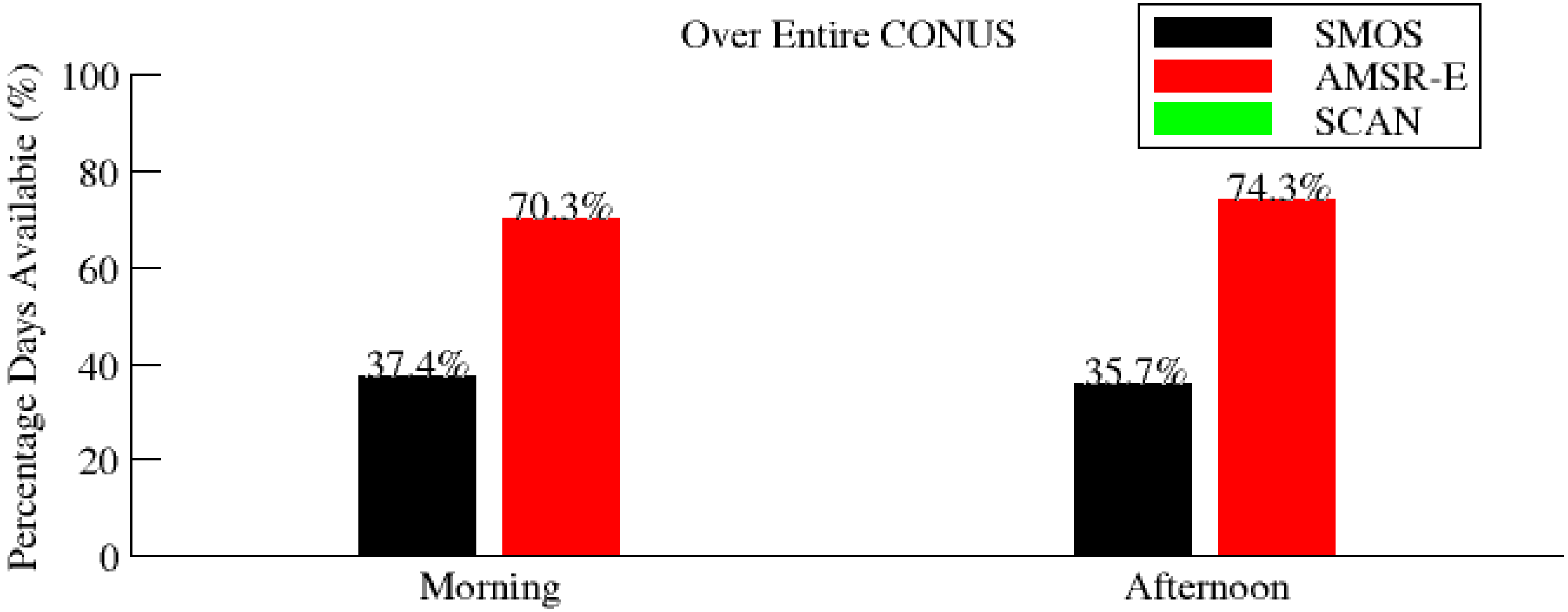
R_{value} Proxy for AMSR-E

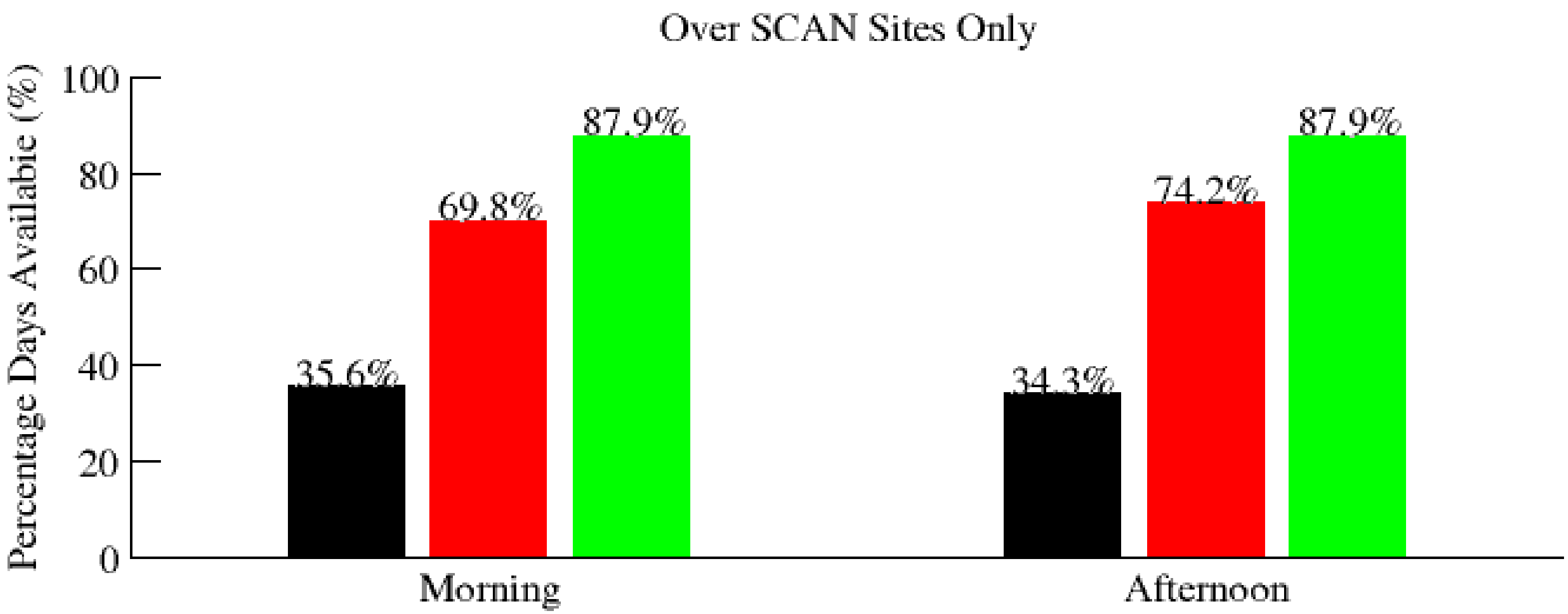
Number of Available 5-day Windows

R_{value} Calculated with 5-day windows

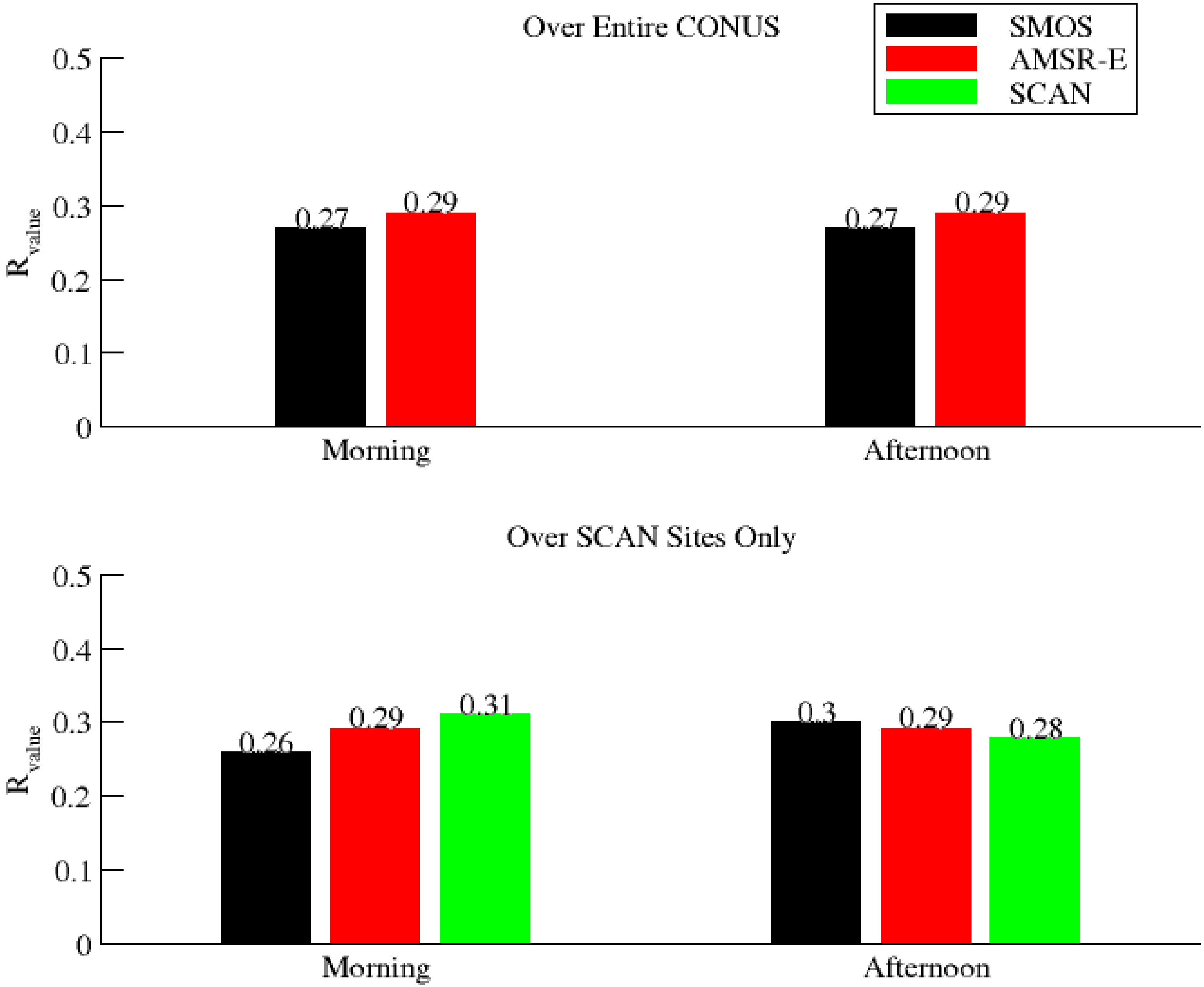


Data Availability

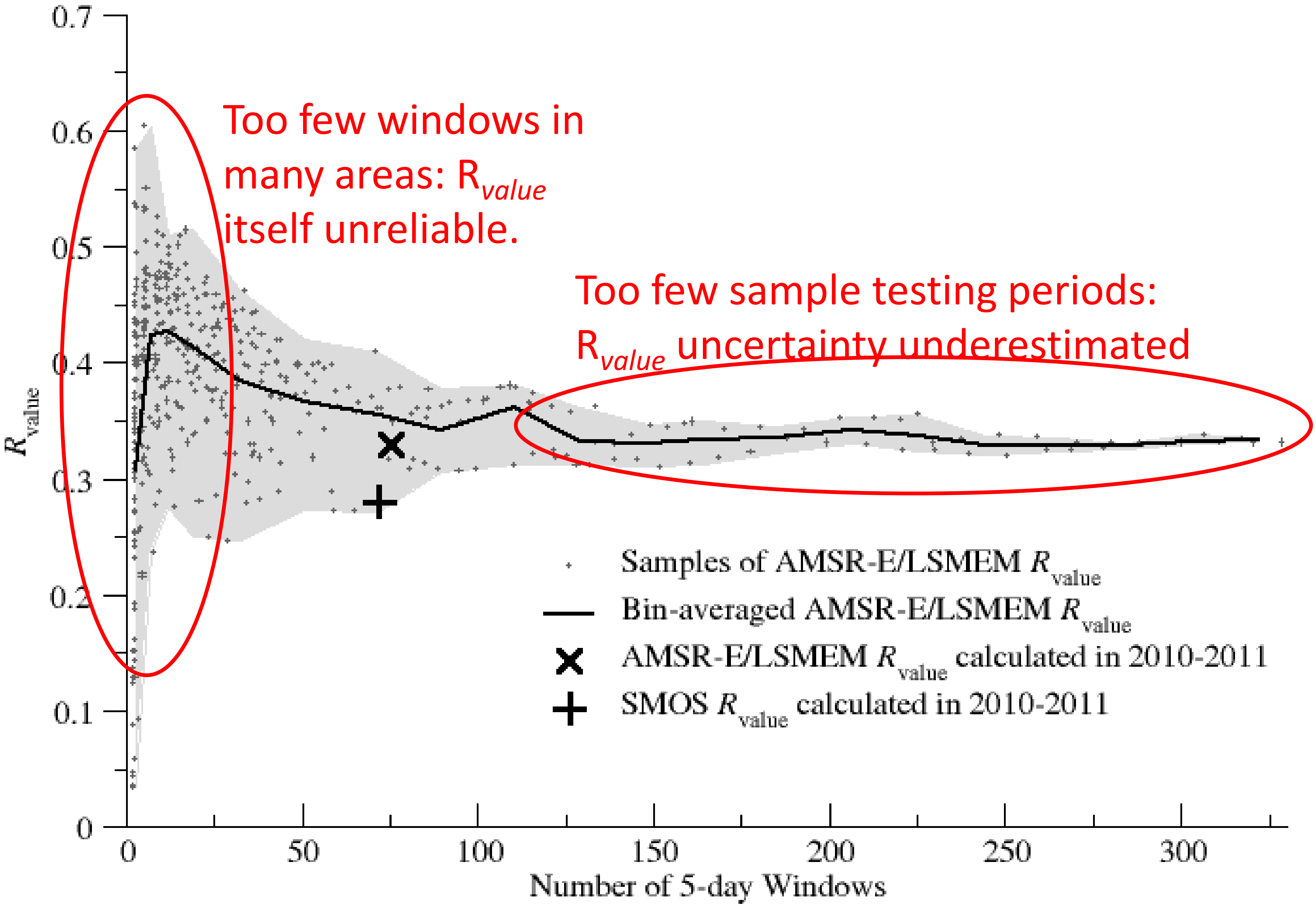




Summary: R_{value} Calculated with 5-day windows



R_{value} Robustness vs Testing Period Length



Comments

- SMOS produces significantly fewer retrievals than AMSR-E
- R_{value} Proxy relies heavily on the availability of retrievals, and more retrievals help better depicting the rain-moisture response
- With same number of days when AMSR-E and SMOS data are available, SMOS achieves similar skill as AMSR-E and SCAN. The spatial patterns are similar for SMOS and AMSR-E – lower in the densely vegetated east, and higher toward the central and west CONUS regions.
- The definition of R_{value} Proxy works to the advantage of AMSR-E because it focuses on significant rain events, and the SMOS screens out a lot of wet peaks. Also, the good performance of SMOS in dry periods gets suppressed by the definition of R_{value} Proxy.

Thank You!